Alberta

ENVIRONMENT

WATER QUALITY EVALUATION OF

BUFFALO LAKE STABILIZATION PROJECT

Planning Division
Water Resources Management Service
Alberta Environment
August 1989

WATER QUALITY EVALUATION OF BUFFALO LAKE STABILIZATION PROJECT

Planning Division
Water Resources Management Service
Alberta Environment
August 1989

90-00262/

EXECUTIVE SUMMARY

Buffalo Lake is a large, shallow, moderately saline lake. Algal blooms are rare in Buffalo Lake because of the inhibiting effect of high salinity on algal production.

The lake is a popular recreational area. Lake level fluctuations have reduced the recreational attractiveness of the lake and have hampered orderly development of the shoreline.

In 1978, Alberta Environment began a study to assess the feasibility of stabilizing the water level of Buffalo Lake. The two-phase study, completed in 1982, concluded that it was technically feasible to divert water from the Red Deer River to Buffalo Lake via Parlby Creek.

The volumes of Red Deer River water that would be required to stabilize Buffalo Lake are relatively small compared to lake volume. On average, the annual volume of river water required is about 4 percent of the total lake volume.

These earlier studies concluded that the project could, however, have adverse environmental effects, namely an increase in algal and macrophyte biomass due to the addition of phosphorus and a decrease in lake salinity.

A third phase of studies was conducted in 1983 to further investigate the possibility of negative water quality impacts. The various Phase III reports were summarized by Alberta Environment in 1984 and 1987 and predictions from the two-phase study were reiterated. Due to other water management commitments and priorities, it was decided in 1984 that the stabilization project would not proceed at that time.

This report examines the water quality predictions made in earlier reports in light of recent water quality data. Emphasis is placed on predicting project impacts on Buffalo Lake phosphorus, salinity and algal biomass levels.

This evaluation concludes that:

1. Although Red Deer River water has higher phosphorus concentrations than Buffalo Lake on average, post-project annual areal phosphorus loads to Buffalo Lake will not increase significantly (only 3 percent under worst case pumping conditions).

2. The change in lake phosphorus concentrations expected from this increase in annual areal load is likely to be small enough that it will be masked by the natural seasonal and annual variability in Buffalo Lake phosphorus concentrations.

3. Salinity levels in Buffalo Lake will decrease. The magnitude of this decrease and how fast it will occur depends on the lake level when pumping begins, the pumping requirements in the following years, and the extent of surface outflow and groundwater exchange.

4. Algal biomass will increase. Because salinity affects algal production, the magnitude and timing of this change will depend on changes in lake salinity. However, even if salinity is reduced to levels that do not inhibit algal production, algal biomass will not increase to values beyond the range found in other Alberta recreational lakes.

TABLE OF CONTENTS

		PAGE
	EXECUTIVE SUMMARY	i
	TABLE OF CONTENTS	iii
	LIST OF TABLES	v
	LIST OF FIGURES	v
1.0	INTRODUCTION	1
	1.1 Background	1
	1.2 Project Description	2
2.0	COMPARISON OF RED DEER RIVER AND BUFFALO LAKE WATER QUALITY	6
3.0	EFFECTS OF SALINITY AND PHOSPHORUS ON ALGAL GROWTH	12
	3.1 Saline Lake Survey	12
	3.2 Laboratory Algal Assays	13
	3.3 Field Bag Experiments	13

		PAGE
4.0	PHOSPHORUS INPUTS TO BUFFALO LAKE	14
4.1	Phosphorus Inputs - Natural Condition	14
4.1.1	Parlby Creek	14
4.1.2	Atmospheric Deposition	14
4.1.3	Diffuse Surface Drainage	15
4.1.4	Cottages	15
4.1.5	Internal Loading	15
4.2	Phosphorus Inputs - Lake Stabilization	17
5.0	EFFECTS OF LAKE STABILIZATION ON PHOSPHORUS, SALINITY AND ALGAL BIOMASS LEVELS	21
5.1	Phosphorus	21
5.2	Salinity	21
5.3	Algal Biomass	23
6.0	CONCLUSIONS	24
7.0	REFERENCES	26
8.0	ACKNOWLEDGEMENTS	27

LIST OF TABLES

		Page
Table 1	Estimate of Red Deer River Water Necessary to Stabilize Buffalo Lake Levels, 1957 to 1983	4
Table 2	Buffalo Lake Morphometry	5
Table 3	Red Deer River at Red Deer Mean Monthly Flow (m^3/s), 1984-1988	5
Table 4	Mean Concentration of Ions (mg/L), Conductivity (mmhos/cm) and pH in Buffalo Lake (Main and Secondary Bays) and the Red Deer River	6
Table 5	Average Total Phosphorus Concentrations (mg/L) in Buffalo Lake, Main Bay and Red Deer River, May-October, 1981-1986	10
Table 6	Annual Total Phosphorus Inputs to Buffalo Lake (mg/m^3)	18

LIST OF FIGURES

Figure 1	Project Layout	3
Figure 2	Red Deer River and Buffalo Lake Conductivity, 1981-1987	7
Figure 3	Red Deer River Total Phosphorus and Total Dissolved Phosphorus, 1981-1987	9
Figure 4	Buffalo Lake Total Phosphorus and Total Dissolved Phosphorus, 1981-1986	11
Figure 5a.	Phosphorus Inputs to Buffalo Lake - Natural Condition	20
Figure 5b.	Phosphorus Inputs to Buffalo Lake with Lake Stabilization (Average Case)	20
Figure 5c.	Phosphorus Inputs to Buffalo Lake with Lake Stabilization (Worst Case)	20

1.0 INTRODUCTION

1.1 Background

Buffalo Lake is a large, shallow, moderately saline lake. Algal blooms are rare, because of the inhibiting effect of high salinity on algal production. The lake is a popular recreational area. Lake level fluctuations have reduced the recreational attractiveness of the lake and have hampered orderly development of the shore line.

In 1978 Alberta Environment began a study to assess the feasibility of stabilizing the water level of Buffalo Lake. The major conclusion of the two-phase study, completed in 1982, was that a project to divert water from the Red Deer River to Buffalo Lake via Parlby Creek was technically feasible. The project could, however, have adverse environmental effects, namely an increase in algal and macrophyte biomass due to the addition of phosphorus and a decrease in lake salinity. The possibility exists that the stabilization of the lake level to enhance recreational use could instead detract from the lake's recreational potential.

A third phase of studies was conducted in 1983 to further investigate this possibility and to quantify the extent to which nuisance aquatic algal and macrophyte growth might develop. The various Phase III reports were summarized by Alberta Environment, Planning Division in 1984 and 1987 and predictions from the previous two-phase study were reiterated. Due to other water management commitments and priorities, it was decided in 1984 that the stabilization project would not proceed at that time.

Renewed interest in the Buffalo Lake stabilization project at present warrants a re-examination of past water quality studies and an evaluation of information collected since 1984. This report briefly

reviews the Phase III water quality summaries and examines predictions made in earlier reports in light of new data. Emphasis is placed on predicting project impacts on Buffalo Lake phosphorus, salinity and algal biomass levels.

1.2 Project Description

The project involves pumping water from the Red Deer River via pipeline and canal to Alix Lake and a channelized Parlby Creek to convey the water to Buffalo Lake (Figure 1). Tail Creek would be channelized and an outlet control structure would be built to control outflow from the lake.

The diversion pump capacity is 75 cubic feet per second (cfs) or 2.12 cubic metres per second (m^3/s), with a maximum pumped volume in any month totalling 4.69 million cubic metres (m^3). Estimates of pumped water requirements for a 27 year period (1957 - 1983) were simulated (Acres, 1982, Addendum, 1984) and ranged from 0 to a maximum of 28.14 million m^3 over the May to October pumping period in a year (Table 1). Average pumped volume was 11.64 million m^3. No pumping would have been required from 1970 through 1974. High pumped volumes would have been required for most of the May to October period in 1958 through 1964.

Tables 1 and 2 show that in a dry year when maximum pumping would be required, the volume pumped is about 80 percent of the volume of Secondary Bay, or about 10 percent of the total lake volume. On average, the pumped volume is less than one third of the Secondary Bay volume or about 4 percent of the total lake volume.

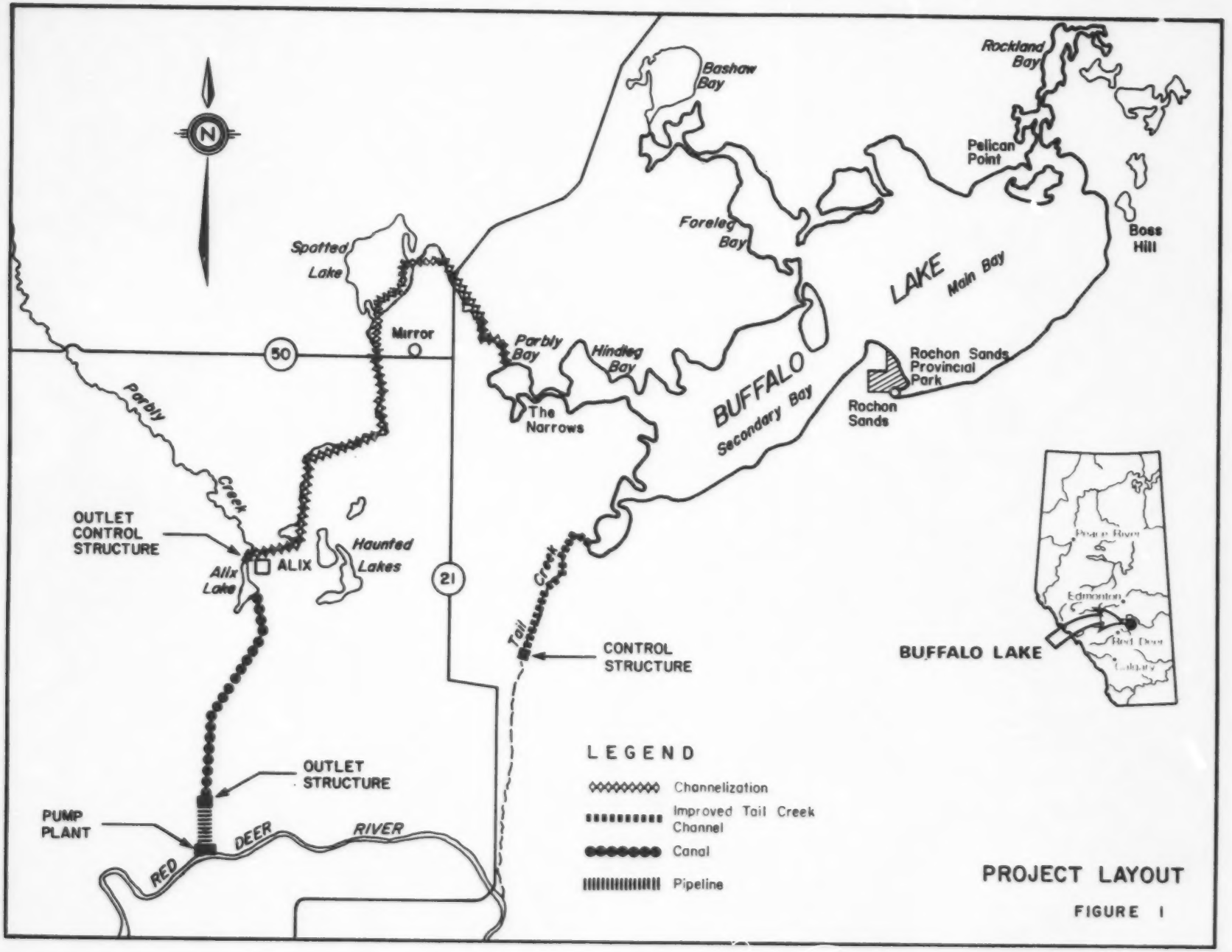

N
Bashaw Bay
Rockland Bay
Pelican Point
Foreleg Bay
Boss Hill
Spotted Lake
Mirror
50
Parbly Bay
Hindleg Bay
LAKE
Main Bay
BUFFALO
Secondary Bay
Rochon Sands Provincial Park
Rochon Sands
The Narrows
Parbly Creek
OUTLET CONTROL STRUCTURE
ALIX
Alix Lake
Haunted Lakes
21
Tail Creek
CONTROL STRUCTURE
BUFFALO LAKE
Peace River
Edmonton
Red Deer
Calgary
OUTLET STRUCTURE
PUMP PLANT
RED DEER RIVER
LEGEND
Channelization
Improved Tail Creek Channel
Canal
Pipeline
PROJECT LAYOUT
FIGURE 1

TABLE 1

ESTIMATE OF RED DEER RIVER WATER
NECESSARY TO STABILIZE BUFFALO LAKE LEVELS
1957 to 1983*

SUMMARY OF WATER PUMPED (million m^3)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	TOTAL
1957	0.50	5.40	0.00	0.00	0.00	0.00	0.00
1958	4.07	3.91	4.07	0.00	0.00	4.67	16.74
1959	0.00	3.61	4.69	4.69	4.69	4.69	22.35
1960	0.00	0.00	0.00	4.69	4.69	4.69	14.06
1961	4.07	4.69	4.38	4.69	4.69	4.69	27.19
1962	4.38	4.22	4.38	4.53	4.69	4.68	26.88
1963	4.69	3.76	3.76	4.69	4.69	4.69	26.26
1964	4.07	3.45	3.76	4.69	4.69	4.69	25.34
1965	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	0.00	0.00	0.00	0.00	0.00	4.69	4.69
1967	0.00	0.00	0.00	0.00	4.69	4.69	9.37
1968	4.69	4.07	4.69	4.69	4.69	4.69	27.50
1969	0.00	0.00	3.14	4.69	4.69	4.69	17.20
1970	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	4.69	4.69	9.37
1976	0.00	0.00	0.00	4.38	4.69	4.69	13.75
1977	4.69	4.69	4.69	4.69	4.69	4.69	28.14
1978	0.00	0.00	0.00	4.69	4.69	0.00	9.37
1979	0.00	0.00	0.00	0.00	4.69	4.69	9.37
1980	0.00	4.69	0.00	0.00	0.00	0.00	4.69
1981	0.00	0.00	3.76	4.22	4.69	4.69	17.35
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.00	0.00	0.00	0.00	0.00	4.69	4.69
TOTAL	30.44	37.08	41.30	55.30	70.28	79.65	314.25

* Acres 1982, Addendum 1984.

TABLE 2

BUFFALO LAKE MORPHOMETRY
(1957 - 1983)

	Natural	Simulated Project Conditions
Lake Level (m)	780.22	780.76
Surface Area (ha)	9,567	11,751
Volume (million m^3)		
Main Bay	237	281
Secondary Bay	35	42
Total Lake	272	323
Mean Depth (m)	2.8	2.8

The change in mean lake level and the corresponding changes in surface area, volume and mean depth for Buffalo Lake with the pumping project over this simulation period are shown in Table 2.

Lake level increased on average by 0.54 m. Surface area and lake volume increased by 23 and 19 percent, respectively. The increase in Buffalo lake water level did not result in an increase in mean depth.

The diversion rates required from the Red Deer River are small in relation to post-Dickson Dam river flows. The maximum withdrawal of 2.12 m^3/s from the Red Deer River represents about 3 percent of the river flow in July and 5 percent of the flow in October (Table 3). It should be noted that the 1984-1988 flows for the Red Deer River included four natural low flow years, so that over the longer term the proportion of flow the diversion represents will likely be less than shown.

TABLE 3

Red Deer River at Red Deer, Mean Monthly Flow
(m^3/s), 1984-1988

May	44.7	August	51.4
June	45.8	September	49.0
July	65.4	October	39.5

2.0 COMPARISON OF RED DEER RIVER AND BUFFALO LAKE WATER QUALITY

Buffalo Lake and the Red Deer River upstream of Content Bridge were sampled intensively over the 1980-1983 period, with water quality sampling continuing at a reduced level since 1985. Lake and river water quality are very different as shown in Table 4.

Table 4. Mean Concentration of Ions (mg/L), Conductivity (mmhos/cm), and pH in Buffalo Lake (Main and Secondary Bays) and the Red Deer River.

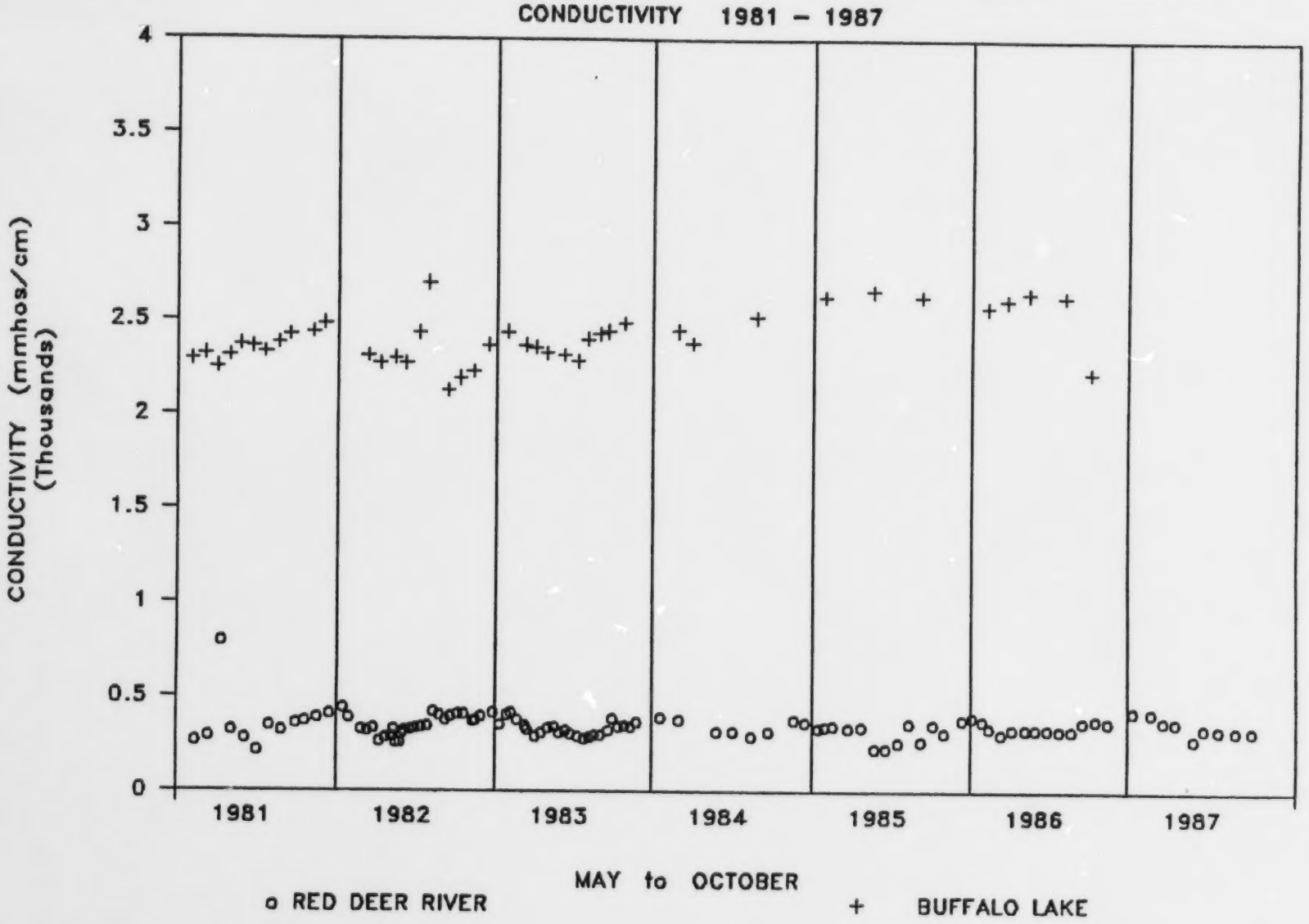
	Main Bay		Secondary Bay		Red Deer River
	1980-83(n=62)	1984-86(n=12)	1980-83(n=63)	1985-86(n=8)	1981-88(n=131)
Sodium	490	533	437	428	12
Magnesium	71	79	66	67	15
Potassium	35	39	32	34	2
Sulphate	399	411	347	344	33
pH *	9.2	9.2	9.0	9.1	8.1
Carbonate	152	165	115	121	2
Bicarbonate	944	993	911	846	196
Calcium	9	7	14	11	44
Conductivity	2412	2593	2191	2170	372

* median

Major ion concentrations, with the exception of calcium, are all much greater in Buffalo Lake than in the Red Deer River, as are pH and conductivity (a measure of salinity). Calcium is higher in river water than in Buffalo Lake. Note that the water quality throughout Buffalo Lake varies between bays, with Secondary Bay having lower concentrations of ions (except calcium) and salinity.

Conductivity levels in the lake and river are shown in Figure 2. Buffalo Lake conductivity is consistently much higher than that in the Red Deer River.

FIGURE 2 RED DEER RIVER & BUFFALO LAKE



Year to year and seasonal variability is evident for total phosphorus in the Red Deer River (Figure 3 and Table 5). Phosphorus concentrations remained low throughout the May to October period in 1984, 1985 and 1987 and in most of 1983. Highest phosphorus concentrations were measured in May, June and July, with this being particularly evident in 1981, 1982 and 1986. On average 80 percent of total phosphorus is dissolved phosphorus, a form readily available for plant growth.

In an earlier report, the low phosphorus concentrations in the Red Deer River in 1983 were considered unusual and it was predicted that summer phosphorus values may increase in the future (Alberta Environment, 1987). The data base through 1987 does not support this prediction. In fact, 1985 and 1987 values were even lower than 1983 values (Figure 3). It should be noted that four of the five years between 1983 and 1987 were low flow years and that sampling was less frequent in 1984 to 1986 than in 1981 to 1983, hence phosphorus spikes could have been missed.

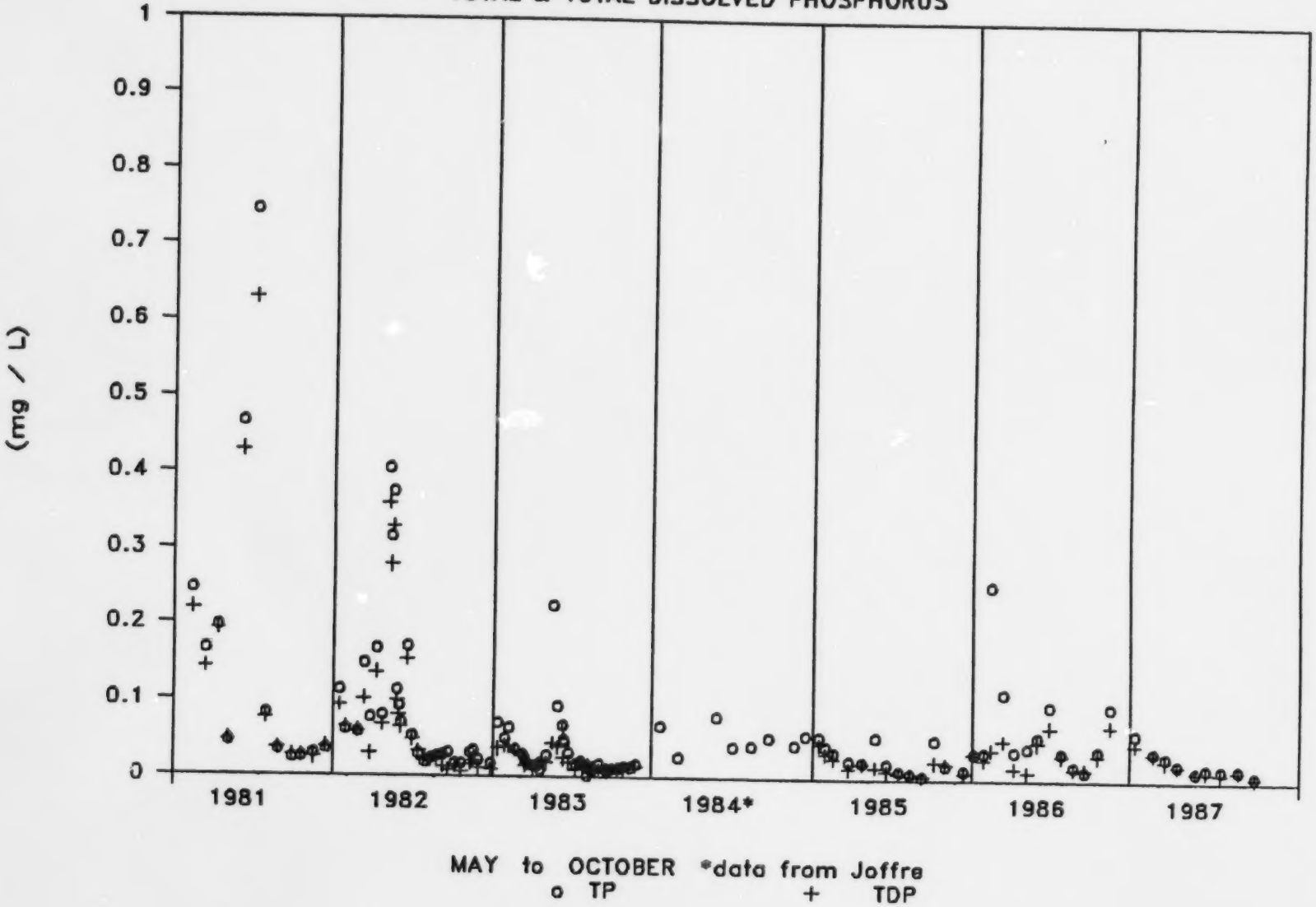
Table 5 shows that Buffalo Lake phosphorus concentrations are much less variable from month to month and year to year compared to the Red Deer River. While the overall average total concentration of phosphorus in the river is higher than in the lake, in three of six years the river has lower average concentrations. Although there are no phosphorus data from Buffalo Lake in 1987, the river is likely lower for that year too, since average values were 0.027 milligrams per litre (mg/L), lower than in either of the previous years sampled (Table 5).

It should be noted that phosphorus concentrations in Buffalo Lake, Main Bay did not clearly increase over the summer in each of 1981, 1982 and 1983, leading to an earlier conclusion that there was no internal phosphorus loading (Alberta Environment, 1987). In subsequent years, however, there are indications of internal phosphorus loading, as concentrations increased from spring through fall in 1984, 1985 and 1986. (Table 5 and Figure 4).

FIGURE 3

RED DEER RIVER

TOTAL & TOTAL DISSOLVED PHOSPHORUS



MAY to OCTOBER *data from Joffre

o TP + TDP

Table 5

Average Total Phosphorus Concentrations (mg/L)
in Buffalo Lake, Main Bay and Red Deer River
May-October, 1981-1986

Buffalo Lake, Main Bay

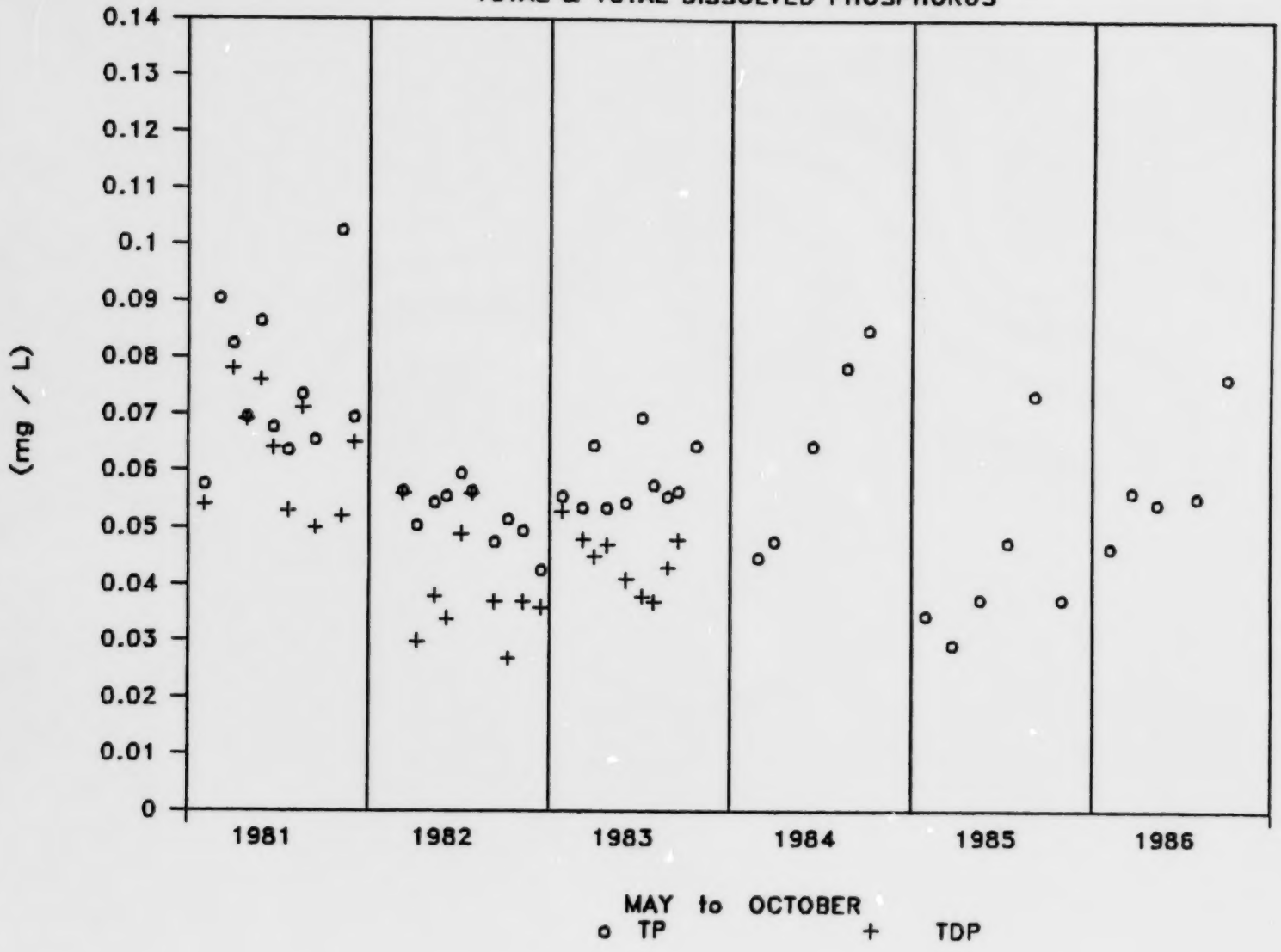
	May	June	July	Aug	Sept	Oct	May-Oct $\bar{x}$	n	Range
1981	.075	.077	.078	.069	.066	.087	.075	11	.058-.103
1982	-	.054	.056	.058	.050	.047	.053	10	.043-.060
1983	.056	.058	.055	.061	.061	-	.058	10	.054-.070
1984	.045	.048	.065	.079	.086	-	.065	5	.045-.086
1985	.035	.030	.038	.048	.056	-	.041	5	.030-.074
1986	.057	.055	.055	.056	.077	-	.060	5	.047-.077
Monthly $\bar{x}$	.054	.054	.058	.062	.066	.067	6 year $\bar{x}$ .059		

Red Deer River

	May	June	July	Aug	Sept	Oct	May-Oct $\bar{x}$	n	Range
1981	.250	.186	.423	.061	.028	.036	.164	12	.027-.750
1982	.082	.123	.203	.028	.027	.029	.082	28	.020-.410
1983	.063	.022	.089	.016	.014	.019	.037	35	.004-.230
1984	.051	-	.064	.046	.056	.054	.054	8	.029-.083
1985	.047	.026	.041	.012	.028	.015	.028	13	.007-.059
1986	.113	.079	.069	.031	.029	.100	.070	13	.016-.260
Monthly $\bar{x}$	.094	.078	.130	.030	.028	.042	6 year $\bar{x}$ .073		

FIGURE 4 BUFFALO LAKE

TOTAL & TOTAL DISSOLVED PHOSPHORUS



Phosphorus concentrations in Secondary Bay were consistently higher than in Main Bay (May to October averages ranging from 0.072 mg/L to 0.084 mg/L, with a five year average of 0.078 mg/L.) The increase in concentration from May through October was evident in 1985 and 1986, as for Main Bay. Secondary Bay was not sampled in 1984.

Average summer chlorophyll-a, a measure of algal biomass, is about three times lower in Buffalo Lake than would be predicted using an equation derived for Alberta lakes which relates total phosphorus to chlorophyll (Prepas and Trew, 1983). Main Bay chlorophyll concentrations averaged 0.007 mg/L and Secondary Bay averaged 0.013 mg/L. The salinity of the lake appears to be inhibiting algal production.

The water quality implications of adding Red Deer River water to Buffalo Lake are described below.

3.0 EFFECTS OF SALINITY AND PHOSPHORUS ON ALGAL GROWTH

3.1 Saline Lake Survey

A survey of 16 saline lakes in Alberta (including Buffalo Lake) was undertaken in 1983 to establish the relation between algal productivity, salinity and the concentration of phosphorus and other nutrients (Bierhuizen and Prepas, 1985). Results showed that algal biomass (chlorophyll) is inhibited by high concentrations of sodium, magnesium, sulphate, bicarbonate, carbonate, high conductivity and high pH. Algal biomass is increased by total phosphorus and calcium. Note that the parameters which are high in Buffalo Lake are those found to limit algal production. These parameters are low in river water. Conversely, calcium and phosphorus, parameters which are positively correlated with algal growth, are higher in river water than in Buffalo Lake.

The relation between total phosphorus and chlorophyll production in saline lakes was found to be positive, however algal production is less than that which would be predicted in non-saline lakes. An equation was developed to predict chlorophyll levels if phosphorus concentration and conductivity are known. Data indicate that as conductivity decreases, algal production will increase even if the phosphorus concentration remains the same.

3.2 Laboratory Algal Assays

Buffalo Lake water and Red Deer River water were assayed both singly and in various mixtures to determine their potential to grow algae. The mixtures of the two waters produced many times the algae than did Buffalo Lake water alone, and this held true whether the phosphorus concentration in the river water was greater than or less than that of the lake.

The two lab species of algae tested showed different responses to salinity and phosphorus, indicating that a change in species composition and dominance may occur if the salinity of Buffalo Lake is reduced. Algal assays are described in much more detail in Alberta Environment reports from 1984 and 1987.

3.3 Field Bag Experiments

Mixing of Red Deer River and Buffalo Lake waters in 60 gal plastic bags suspended in the lake was undertaken four times in 1983. The natural assemblage of algae in the waters at the time of mixing was incorporated into the bags. While numerous problems were encountered and results were highly variable, the bag experiments did show a positive correlation between phosphorus concentration and algal growth in mixtures of the two waters. The effect of salinity reduction was not as evident as in the lab assays. The bag experiments indicated that when Red Deer River water has phosphorus concentrations equal to or more than Buffalo Lake, increased algal growth is likely to result.

More details of these experiments are provided in 1984 and 1987 Alberta Environment reports.

4.0 PHOSPHORUS INPUTS TO BUFFALO LAKE

Phosphorus is regarded as the nutrient which most frequently limits algal and macrophyte growth in lakes. The present sources of phosphorus loading to Buffalo Lake include inputs from Parlby Creek, atmospheric deposition, diffuse surface drainage, inputs from cottages and internal loading from lake sediments or groundwater inflow. The diversion of Red Deer River water to stabilize Buffalo Lake levels will be an additional source of phosphorus. Estimates of current loadings and increased loadings with the stabilization project in place are provided below.

4.1 Phosphorus Inputs - Natural Condition

4.1.1 Parlby Creek

Based on six years of phosphorus monitoring data (1981-83, 1985-87) and the monthly flow volumes of Parlby Creek, the phosphorus input to Buffalo Lake was calculated for each month, then totalled for each of the six years. The average was determined and this amount was reduced by 10 percent to consider phosphorus retention in Parlby Bay consistent with the analysis done by Alberta Environment, 1987. Average annual loading calculated in this manner was 2156 kilograms (kg) or 7.9 milligrams per cubic metre (mg/m^3).

4.1.2 Atmospheric Deposition

The rate of phosphorus deposition from the atmosphere to Buffalo Lake has not been measured. An average rate for Alberta is estimated at 0.22 kilograms per hectare per year (kg/ha/yr) (P. Mitchell, Alberta Environment, Environmental Quality Monitoring Branch, pers. comm.).

Buffalo Lake, with an area of 9567 hectares (ha) on average under natural conditions (1957-1983) (Table 2), would receive 2105 kg/yr or 7.7 mg/m^3 per year from this source.

4.1.3 Diffuse Surface Drainage

A phosphorus export coefficient was determined using Parlby Creek phosphorus data and flow records. The land use patterns in the Buffalo Lake drainage area are similar enough to those in the Parlby Creek Basin that it was felt that using the phosphorus export coefficient derived for the Parlby Creek basin is more realistic than using the theoretical values available. Based on a drainage area of 54,433 ha (excluding Parlby Creek basin and the lake surface), an average loading of 2068 kg or 7.6 mg/m^3 per year was calculated.

4.1.4 Cottages

The phosphorus output per capita is estimated at 0.93 kg per year (Alberta Environment, Environmental Quality Monitoring Branch). Assuming 0.66 mean capita years per cottage and based on the number of cottages (368 cottages as of 1988), the phosphorus loading from this source would be 226 kg or 0.8 mg/m^3 per year.

4.1.5 Internal Loading

Recycling of phosphorus from the bottom sediments back into the water column is a common occurrence in Alberta lakes. It can occur in deep thermally stratified lakes as well as in shallow mixed lakes and under anaerobic or aerobic conditions (P. Mitchell, Alberta Environment, Environmental Quality Monitoring Branch, pers. comm.). While there is no clear evidence of internal loading from 1981, 1982 and 1983 Buffalo Lake data, there is evidence in 1984, 1985 and 1986. The increase in phosphorus concentration that occurs from May to September in 1984, 1985 and 1986 cannot be accounted for by lake volume changes or by external inputs. Therefore internal loading must be occurring.

Internal loading was calculated by difference. The increase in total phosphorus concentration that occurred from May to September in 1984, 1985 and 1986 was equated to an increase in phosphorus mass. The mass entering via Parlby Creek was determined from measured phosphorus concentrations and flows over the June to September period, the mass from atmospheric deposition was considered to be a portion of the annual rate, and the mass entering from diffuse surface drainage was assumed to arrive in the lake in equal proportion to the monthly vs. total annual flow in Parlby Creek. Results were as follows:

Year	May - September Phosphorus Mass (kg) attributable to internal loading	Sediment Release ($mg/m^2/day$)
1984	8283	0.7
1985	3955	0.4
1986	6630	0.6
1984-1986 $\bar{x}$	6289	0.5

The addition of 6289 kg to 272 million m^3 of water is equivalent to 23.1 mg/m^3. This is an underestimate of the annual internal phosphorus load because the loss of phosphorus from the water column to lake sediments has not been taken into account, nor has internal loading in the months of October through April. Internal loading in the fall and winter months could be considerable. A sediment release rate of 1.0 $mg/m^2/day$ for Buffalo Lake was calculated by Alberta Environment, Environmental Quality Monitoring Branch (cited from HydroQual, 1989).

Total phosphorus loading to Buffalo Lake at present from these sources is estimated at 47.7 $mg/m^3/yr$ (Figure 5). Internal loading contributes approximately half of the total annual phosphorus load, assuming that the internal loading estimates from 1984-1986 are representative.

4.2 Phosphorus Inputs - Lake Stabilization

The surface area and volume of Buffalo Lake will increase as a result of lake stabilization (Table 2). Phosphorus inputs from the atmosphere and lake sediments will increase and inputs from diffuse surface drainage will decrease as a consequence of the increased lake surface area (Table 6, Figure 5). Parlby Creek inflows will move more rapidly through Parlby Bay, resulting in less retention of the incoming phosphorus (approximately 5 percent retention compared to 10 percent).

The diversion of Red Deer River water to Buffalo Lake represents an additional phosphorus input. In order to estimate the increased phosphorus input to Buffalo Lake from the Red Deer River, the volume to be diverted must be determined. This volume was simulated on a monthly basis for the 1957-1983 period (Acres, 1982; Addendum, 1984) and ranges from 0 (no diversion required) in wet years to 28.14 million m^3 in 1977, a hot, dry year. Since the simulated diversion requirements extended only to 1983, whereas the phosphorus data base used extended through 1987, the average monthly diversion rate over the 27 years was assumed and was used in calculating phosphorus loading from 1981 to 1987. Total phosphorus data is from a site on the Red Deer River 4 miles above Content Bridge, with the exception of 1984 data. Since this site was not sampled in 1984, data from a site upstream near Joffre was used. Average phosphorus concentration for May to October of each year was determined. The average annual phosphorus input from the Red Deer River was calculated to be 658 kg, or 2.0 $mg/m^3/yr$, not accounting for losses or gains through the conveyance system or retention in Parlby Bay.

TABLE 6

ANNUAL TOTAL PHOSPHORUS
INPUTS TO BUFFALO LAKE
(mg/m^3)

	Natural[1]	Project	
Parlby Creek[2]	7.9	7.0	
Atmospheric Deposition	7.7	8.0	
Diffuse Surface Drainage	7.6	6.2	
Cottages	0.8	0.6	
Internal Loading	23.1	23.9	
Red Deer[3] River diversion water		Average 2.0	Worst Case 4.6
Total volumetric load (mg/m^3)	47.1	47.7	50.3
Total areal load (g/m^2)	0.134	0.131	0.138

1 Lake areas and volumes for natural versus project conditions as shown in Table 2 (based on 1957-1983 simulation).

2 Assumes 10 percent loss of phosphorus due to retention in Parlby Bay under natural conditions, 5 percent under project conditions.

3 Assumes that no phosphorus is lost or gained along the conveyance route from the Red Deer River to Buffalo Lake and does not account for phosphorus retention in Parlby Creek.

An estimate of phosphorus loadings over a series of dry years, when more water would need to be pumped from the Red Deer River to maintain Buffalo Lake water levels, was determined. Using the Acres simulated volumes, the seven year period from 1958 to 1964 was chosen to represent a worst case situation. Using the average monthly pumped volumes for these seven years, combined with the average monthly total phosphorus values from 1981 to 1987, and estimated phosphorus loading of 1475 kg or 4.6 mg/m^3 per year was calculated.

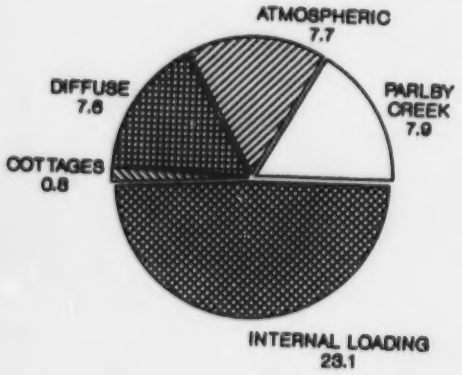
A summary of phosphorus inputs to Buffalo Lake under present conditions and with the stabilization project is provided in Table 6 and is shown in Figure 5.

This analysis indicates that post-project annual phosphorus inputs, whether expressed as mass per surface area or mass per volume, will not increase significantly. The annual areal load is expected to increase by only 3 percent under worst case pumping conditions. In contrast, earlier Phase III assessments (Alberta Environment, 1984 and 1987) concluded that the annual areal load would increase by 31 percent. The decreased significance of the stabilization project on phosphorus inputs can be attributed to:

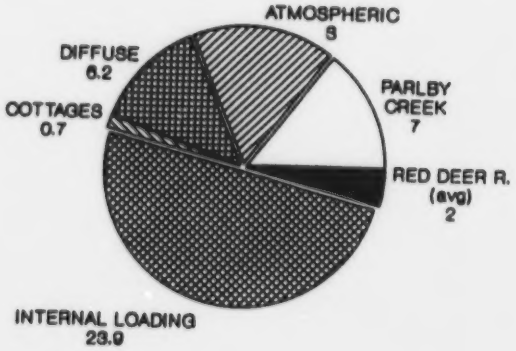
1. A decrease in average monthly phosphorus concentrations in the Red Deer River. This analysis used averages calculated for 1981 through 1987. The earlier assessments were based on averages for 1981 to 1983 only.

2. The recognition of internal loading as an additional phosphorus source. Internal loading was evident in the summers of 1984, 1985 and 1986 and not in 1981, 1982 an 1983. This analysis assumed that the internal loading rates calculated in 1984, 1985 and 1986 are representative of natural conditions. Earlier assessments assumed that internal loading did not occur in Buffalo Lake.

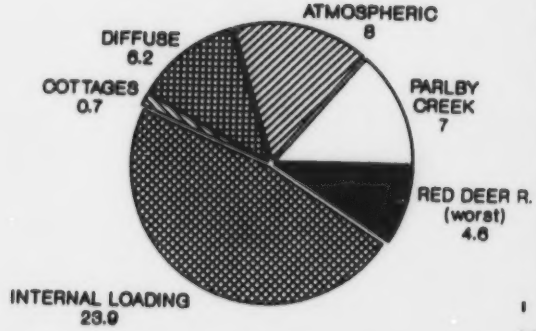
FIGURE 5 PHOSPHORUS INPUTS TO BUFFALO LAKE



5 (a)
NATURAL
mg/m3/yr



5 (b)
STABILIZATION (average case)
mg/m3/yr



5 (c)
STABILIZATION (worst case)
mg/m3/yr

5.0 EFFECTS OF LAKE STABILIZATION ON BUFFALO LAKE PHOSPHORUS, SALINITY AND ALGAL BIOMASS LEVELS

5.1 Phosphorus

It is difficult to predict post-project phosphorus concentrations in Buffalo Lake. The incoming phosphorus can be taken up by aquatic plants, released to the water as plants decay and eventually lost through sedimentation or outflow (surface water or groundwater). In freshwater lakes, approximately 75% of the annual phosphorus is sedimented out over the course of a year (cited from Alberta Environment, 1987). Sedimentation rates are much less in saline lakes (cited from HydroQual, 1989).

Annual phosphorus inputs to Buffalo Lake under natural conditions are almost as high as the existing mass of phosphorus in Buffalo Lake. No surface outflow has occurred from Buffalo Lake since 1929. If sedimentation was the only process to account for phosphorus losses, phosphorus levels in Buffalo Lake would have increased dramatically since 1929 and existing levels would be 5 to 10 times higher, as in saline lakes such as Eagle and Cooking lakes (H. Hamilton, HydroQual, pers. comm.).

It is highly unlikely that the minor increase in annual areal phosphorus load to Buffalo Lake will result in noticeable increases in phosphorus concentrations. Any changes will probably be masked by the natural seasonal and annual variability in Buffalo Lake phosphorus concentrations.

5.2 Salinity

The prediction of post-project salinity levels is dependent on a number of factors including the lake level at project initiation, pumping requirements in subsequent years, extent of surface outflow and the role of groundwater in the lake's water balance. These factors all

have a degree of uncertainty associated with them, hence predictions of changes to salinity levels are general in nature.

The addition of Red Deer River water to Buffalo Lake represents an addition of salt, although the river water is much fresher than the lake and than the groundwater surrounding the lake. The initial effect of the river water as the lake elevation is raised is a dilution effect. Subsequently, however, if river water is added only to replace the water lost through evaporation, the lake's salt level could still increase if there is no outflow.

If a series of wet years occurs following project implementation, no pumping may be required for extended periods; conversely if a series of dry years occurs, heavy pumping would be required to stabilize the lake. Under a no pumping scenario, salinity will continue to follow natural patterns whereas under heavy pumping there could be a decrease in lake salinity as more fresh river water dilutes the lake.

Surface outflow can occur if the lake is brought up to the desired elevation in fall and if runoff in the following spring is an above average amount. This would lead to a decrease in salinity because the inflows would be fresher water than the lake, whereas outflow would be mainly more saline lake water.

The role of groundwater in the lake's water balance is not well understood. Groundwater inflow has been measured, but an outflow has not been detected. If there is a groundwater outflow, it would provide a removal mechanism for salts. Hence the prediction that lake salinity would increase (based on the assumption that water is only added to replace that lost through evaporation), would no longer be valid. If groundwater exchange is significant and one assumes that the lake is presently at equilibrium, and that pumping will perturb the equilibrium, then salinity will decrease. Raising the lake level could suppress groundwater inflow and replace it with fresher river water.

Evidence suggests that Buffalo Lake is not a closed hydrologic system (i.e., there must be a groundwater outflow). Salinity levels have not been increasing significantly as would be expected if chemical precipitation and evaporation were the only removal mechanisms. Total phosphorus levels would also be much higher if there were no outflow (see Section 5.1). The analysis of pollen throughout the layers of a lake sediment core indicated that salt-tolerant plants have lived in Buffalo Lake for thousands of years. Thus it appears that salinity levels in the lake are at a steady state, with salts being removed at the same rate that they are added.

Assuming that groundwater exchange is significant in the water balance of Buffalo Lake and that the addition of fresh Red Deer River could alter the present equilibrium, it is predicted that lake salinity will decrease.

5.3 Algal Biomass

Post-project predictions of algal biomass, as chlorophyll-a, are based on predictions of post-project phosphorus and salinity levels.

Previous water quality assessments (Alberta Environment, 1984, 1987) predicted that algal biomass in Buffalo Lake would increase to nuisance levels if the lake was stabilized by adding Red Deer River water. The 1984 study concluded that impacts would be restricted to Secondary Bay whereas the 1987 study concluded that Main Bay would also develop nuisance levels of chlorophyll-a. The different conclusions can be attributed to different predictions of post-project salinity levels as well as slightly different assumptions about the degree of water exchange between Secondary and Main Bays.

If post-project phosphorus levels do not increase and worst case salinity levels are assumed (that is, levels become non-inhibiting), average summer Buffalo Lake chlorophyll-a concentrations would increase from 0.008 to about 0.025 mg/L. It is more probable that salt levels

will not decrease to non-inhibiting levels and average post-project chlorophyll-a concentrations in Buffalo Lake will range from 0.010 to 0.015 mg/L.

Whether this increase impairs the recreational use of Buffalo Lake depends to a large degree on public perception of acceptable chlorophyll-a levels. In general, in North American Lakes, contact recreation is judged to be impaired at chlorophyll-a levels of 0.012 mg/L and restricted at chlorophyll-a levels of 0.025 mg/L (cited from HydroQual, 1989). However, in Alberta, significant water-based recreation occurs in productive lakes where average chlorophyll-a levels range from 0.015 to 0.030 mg/L.

6.0 CONCLUSIONS

1. Buffalo Lake morphometry will change. Lake level, surface area and lake volume will increase by 0.54 m, 23% and 19% respectively, on average. Mean depth will <u>not</u> increase.

2. The annual areal phosphorus load is expected to increase by only 3 percent under worst case pumping conditions. In contrast, earlier assessments concluded that the annual areal load would increase significantly (31 percent). The decreased significance of lake stabilization on phosphorus inputs predicted here can be attributed to the recognition of internal phosphorus loading as an additional phosphorus source and decreased estimates of average monthly phosphorus concentrations in the Red Deer River (1981 to 1987 average values are lower than 1981 to 1983 averages).

3. Changes in Buffalo Lake phosphorus concentrations will likely be small enough that they are masked by natural seasonal and year to year variability. Earlier assessments concluded that significant increases in phosphorus concentrations would occur because annual areal loading rates would increase.

4. Salinity levels in Buffalo Lake will decrease. To what degree and how quickly this occurs depends on:

   i) lake level at the time that pumping begins.

   ii) pumping requirements to stabilize the lake. Pumping requirements are highly variable from year to year. It is possible that pumping requirements will be zero for several years after the lake is initially filled. It is just as possible that maximum pumping will be required for several years after lake filling.

   iii) extent of surface outflow that occurs (depends on lake level, inflows, etc.).

   iv) extent of groundwater exchange (may be influenced by lake level, inflow etc.).

5. Algal biomass will increase. The magnitude and timing of this change depends on changes in lake salinity. Even if salinity decreased to non-inhibiting levels, chlorophyll-a concentrations in Buffalo Lake would not increase to values beyond the range found in other Alberta recreational lakes.

7.0 REFERENCES

Alberta Environment. 1984. Buffalo Lake Regulation Phase III Studies: Water Quality Main Report. Planning Division, Calgary. 60 pp.

Alberta Environment. 1987. Studies into the effect of proposed Buffalo Lake stabilization on algal growth. Planning Division, Edmonton. 122 pp. + app.

Acres Consulting Services Ltd. 1982. Buffalo Lake Regulation Study, Phase II. Modes of Operation. 23 pp. Addendum 1984.

Bierhuizen, J.F.H. and E.E. Prepas. 1985. Relationship between nutrients, dominant ions and phytoplankton standing crop in prairie saline lakes. Can. J. Fish. Aquat. Sci. 42: 1588-1594.

HydroQual Consultants Inc. 1989. Eagle Lake - Restoration Assessment. Prep. for Systems Investments Ltd. 51 pp. + app.

Prepas, E.E. and D.O. Trew. 1983. Evaluation of the phosphorus-chlorophyll relationship for lakes off the Precambrian Shield in Western Canada. Can. J. Fish. Aquat. Sci. 40: 27-35.

8.0 ACKNOWLEDGEMENTS

This report was written by B. Brassard and A. Trimbee, Environmental Assessment Section, Planning Division, Alberta Environment. The authors gratefully acknowledge input from:

1) Planning Division, Alberta Environment

J. R. Hart
J. H. Simpson
J. M. Wuite
F. M. Crompton
D. Thrussell
P. Cross

3) Environmental Assessment Division, Alberta Environment

J. B. Kemper
D. Trew
P. Mitchell
A. Sosiak

4) Technical Services Division, Alberta Environment

S. Figliuzzi
S. Clare

5) HydroQual Consultants Inc., Calgary

H. Hamilton
S. Goudey

(1046I)